CHANGES IN AREA AND DIRECTIONS OF STREAM EROSION IN THE EASTERN PART OF THE HUNGARIAN BASIN (GREAT PLAIN) DURING THE PLIOCENE AND PLEISTOCENE

by

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The last marine sediments of the Hungarian Basin (Great Plain) were deposited in the Lower Pliocene in brackish water of the Pannonian sea. Thereafter, in the Upper Pliocene (Levantian), the Great Plain become a fluvio-lacustric area. The sediments produced in the Upper Pliocene do not cover the territory of the basin, uniformly as subsequent Pleistocene and Holocene alluvial deposits form here and there a direct cover of Pannonian marine sediments, and Upper Pliocene sediments are absent. The upper limit of the Pannonian strata is at various structural depths within the basin. The differences were caused by later movements of the Earth's crust resulting in further differences in the development of regional units. [JASKÓ 1947, KERTAI 1957, KŐRÖSSY 1956, 1957, 1963, ERDÉLYI 1960, CSIKY 1963, RÓNAI 1964].

The eastern part of the Hungarian Basin (Tiszántúl) was filled up by rivers running from the borders: the Zagyva from NW, the Sajó and the Hernád from North, the Bódva and the Tisza from NE, the Szamos, the Körös and the Maros from East, as well as by their predecessors.

We have data on the historical development of the river system of Tiszántúl in plenty. [SÜMEGHY 1944, ERDÉLYI 1960, SOMOGYI 1961, BULLA 1962, URBANCSEK 1960, 1962.] Yet the heavy-mineral composition of the Pliocene and Pleistocene sandy sediments have not been analyzed so far although a knowledge of the composition of recent alluvia and their comparison with the former might help in drawing up a correct picture of the palaeohydrographic evolution.

Therefore, similarly to earlier examinations the heavy-mineral composition of further borings has been analyzed. *Figure 1* shows the location of the evaluated borings grouped in profiles.

Profile I *(Figure 2)* contains the borings of Szolnok and Törökszentmiklós. The heavy-mineral composition of the boring of Szolnok is characterized by a lower percentage of hypersthenes (1,7 to 1,9%) and by a higher

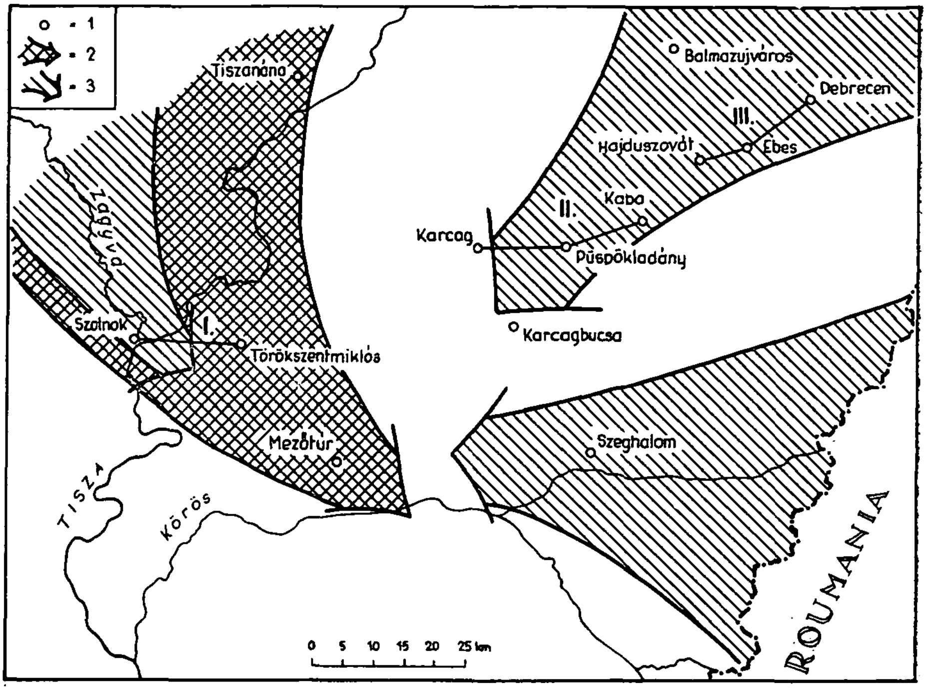

Figure 1. General plan of borings and profiles elaborated so far
1. Situation of the borings
2. Stream-erosion direction of the Palaeo-Zagyva
3. Stream-erosion directions of the sediments whose the composition is similar to that of alluvia of present-day rivers.

amount of garnet (15 to 39%), (See *Figure 2* and Table). By these of his properties it is similar to the alluvia of present Zagyva river, which means that the stream erosion has taken place, also in this case, from the NW *(Figure 1)* [MOLNÁR, 1964]. Sediments of similar composition are known from the borings of Pély and Kisköre, situated to the North of this area. [MOLNÁR 1964]. The composition of samples taken at the greatest depth in the Szolnok boring (309 m) differ from the overlying strata by the absence of hypersthene and brown amphibole, by having a smaller amount of garnet (8,8%) and by a higher percentage of calcite-dolomite (20%). This sediment did not come from the same area as the present alluvia of the Zagyva.

The other boring on Profile I called Törökszentmiklós is situated at 20 km to the Eeast of Szolnok *(Figure 1).* The high amounts of hypersthene (6 to 28%), augite (3 to 9%) and brown amphibole (5,2 to 9,6%) in the material prove that erosion was coming from the E or NE. *I.e.* the alluvia of the Körös and those of the rivers to the NE contain considerable amounts of the above mentioned minerals [MOLNÁR 1964].

Figure 3 shows heavy minerals in samples taken at 25 to 31 metres in the boring of Törökszentmiklós. The light-coloured minerals are, for the most part hypersthenes and augites. The opaque inclusions of hypersthenes as well

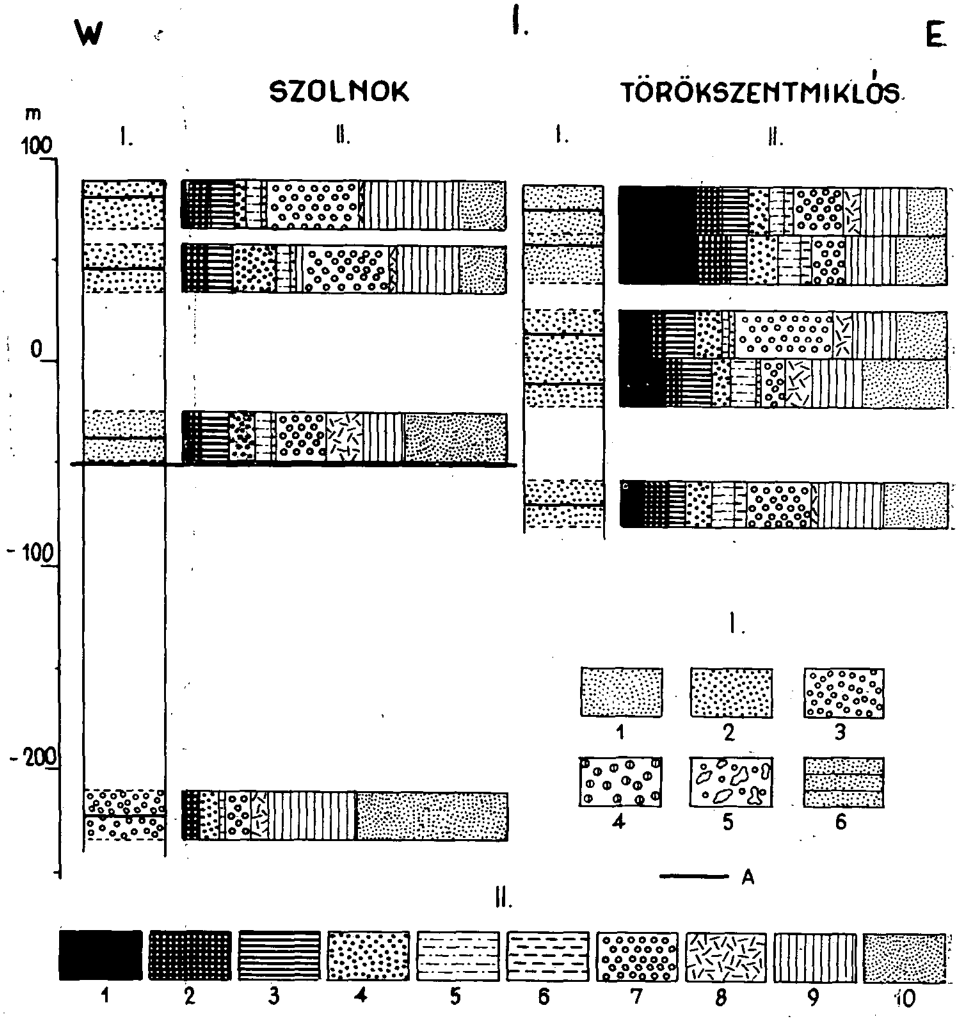

Figure 2 (Profile I)

I. Granulometric composition:
1. Fine sand (0,06 to 0,1 mm)
2. Fine-grain sand (0,1 to 0,2 mm)
3. Medium-grain sand (0,2 to 0,5 mm)
4. Coarse-grain sand (0,5 to 2,0 mm)
5. Gravel
6. Sandstone

II. Heavy-mineral composition:
1. Hypersthene
2. Augite
3. Brown amphibole
4. Magnetite
5. Chlorite
6. Bluish-green amphibole (hornblende)
7. Garnet
8. Limonite
9. Other minerals (total)
10. Weathered mineral

A.: Lower limit of the sediments of the Tisza catchment area.

Mineral composition of the samples investigated

Serial number	Boring		Dominantly magmatic minerals											Dominantly metamorphic minerals														Other minerals						Total quantity of the heavy-minerals in the examined fraction	Diameter of examined fraction in mm	Dominant grain diameter in mm
	LOCALITY	DEPTH m	Hypersthene	Other rhombic pyroxenes	Augite	Diopside	Brown amphibole	Magnetite	Ilmenite	Biotite	Apatite	Titanite	Zircon	Chlorite	Tourmaline	Epidote	Zoisite	Rutile	Bluish green amphibole	Actinolite — tremolite	Anthophyllite	Garnet	Staurolite	Cyanite	Andalusite	Glaucophane	Serpentine	Calcite-dolomite	Glauconite	Pyrite	Limonite	Other micas	Weathered minerals			
1	Szolnok	2,8—9,5	1,9	2,5	6,2	4,9	7,5	3,7			6,2		0,6	4,4	4,4	3,7	0,6	1,2	1,2	3,2		28,9	0,6	0,6	0,6			1,2		0,6	1,9	4	14,4	3,1	0,1—0,125	0,1—0,2
2	Szolnok	41—46	1,3	6,0	4,7	7,7	1,3	6,0			3,3			4,0	2,0	1,3	0,7	1,3	1,3	0,7		39,3	0,7	2,7						0,7	2,7	0,7	14,6	2,7	0,1—0,125	0,1—0,2
3	Szolnok	125—130	1,7		3,7	2.2	3,7	13,0			4,4		0,5	4,9	0,5	1,1			1,7	1,1		15,7	0,5	0,5						0,5	11,3	1,1	31,9	0,8	0,1—0,125	0,05—0,1
4	Szolnok	309—317			4,3	1,3		6,8			0,6			1,3		1,3			0,6	0,6		8,8		0,6	0,6			20,8			4,7	1,3	46,4	11,0	0,1—0,2	0,2—0,5
5	Törökszentmiklós	12—13	22,8	0,5	8,4	0,5	9,6	7,3		1,1	1,7			3,9	2,2	0,5	1,0	1,1	2,8			15,8			0,5						5,1	2,8	12,4	1,9	0,1—0,125	0,1
6	Törökszentmiklós	25—31	23,8	0,5	9,3	1,5	5,7	9,3		1,0	2,1			7,7	1,5			0,5	3,1	2,1		10,3	1,5	0,5							1,5	2,6	15,5	1,5	0,1—0,2	0,1
7	Törökszentmiklós	72—77	9,0	1,7	3,4	1,1	9,6	6,2			4,0			2,8	1,7	0,6		0,6	1,7	1,1		31,1	2,2	0,6				0,6			6,2	0,6	15,2	1,5	0,1—0,2	0,1—0,2
8	Törökszentmiklós	97—99	12,9		4,8	1,1	9,6	5,9		2,7	0,5			7,6	1,1				1,6	3,2		8,1	1,1	0,5				1,1		1,1	6,5	4,8	25,8	1,4	0,1—0,2	0,1—0,2
9	Törökszentmiklós	145—161	6,6	0,9	7,5	0,9	5,2	7,9		0,9	4,3	0,4		7,0	4,7	0,9	0,9	0,4	3,8	2,9		20,1	0,4	1,4						0,4	1,9	0,9	19,7	1,4	0,1—0,125	0,1—0,2
10	Karcag	24—29	21,9	0,6	10,4	1,2	9,8	7,5			0,6			2,9	1,7			0,6	1,7	1,2		12,2	0,6							2,3	6,3		18,5	2,1	0,1—0,2	0,1—0,2
11	Karcag	78—83	9,7		8,1	1,6	4,8	16,1			1,6			21,1	0,5	1,1			1,1			5,4						0,5		1,6	3,2	2,7	19,9	1,9	0,1—0,2	0,1—0,2
12	Karcag	121—124	6,5	1,8	7,7	1,2	9,5	8,9		1,2	2,4			7,1	1,2				3,5	1,2		10,0	0,6	0,6						3,5	4,1	0,6	28,4	1,9	0,1—0,2	0,2—0,5
13	Püspökladány	50—59	11,3	0,5	9,1	1,6	4,8	9,1		4,8	0,5			15,0	1,0	0,5	0,5		0,5	1,0		2,7									3,2	4,8	29,1	2,8	0,1—0,2	0,1—0,2
14	Püspökladány	126—130	16,0		13,5	0,6	9,3	8,0		0,6	1,3			3,7	0,6	0,6			6,2	0,6		11,1	0,6							1,9	1,9	1,3	22,2	5,9	0,1—0,2	0,3—0,5
15	Püspökladány	275—280	6,6	0,5	13,2		11,5	4,9		4,4	1,1			7,7	1,1				2,8	1,6		12,0	0,5							0,5	1,6	1,1	28,9	3,3	0,1—0,2	0,2—0,4
16	Püspökladány	310—315	1,8		5,8		22,7	8,1		1,1	0,6			6,9	0,6				4,7	0,6		20,9						0,6	4,7		3,4		17,5	6,7	0,1—0,2	0,4—0,5
17	Püspökladány	420—425	2,2		2,2		4,4	15,3		0,7				2,2	0,7			0,7		0,7		7,3				0,7				2,2	3,7	2,2	54,8	2,5	0,1—0,2	0,4—0,5
18	Püspökladány	528—531					2,4	20,0						3,7	0,6			1,2	0,6	0,6		23,0	1,2			0,6				0,6	7,9		37,6	2,9	0,1—0,2	0,5—1,0
19	Püspökladány	635—640				0,6	4,1	12,5						2,4	0,6	0,6			1,2			20,8	1,2					0,6		2,4	3,6	0,6	48,8	8,6	0,1—0,2	0,5—1,0
20	Kaba	54—58	11,3	1,0	15,1	1,0	13,5	10,7			1,0			2,1	1,0		0,5	1,6	4,3	1,0		14,6		0,5						1,0	5,7		14,1	2,3	0,1—0,125	0,1—0,2
21	Kaba	124—137	13,8	1,8	18,3	0,6	6,9	10,1		0,6	0,6			5,1	1,2				2,6	0,6		7,6									5,1	1,8	23,3	4,1	0,1—0,125	0,4—0,5
22	Kaba	209—211	23,5	1,5	21,9		2,3	12,4						2,3								10,6										4,6	21,9	11,6	0,1—0,25	0,5—0,7
23	Kaba	216—225	5,1		3,9	1,3	15,4	10,9						1,9	0,6	1,3			1,9	1,3		27,6								3,2	4,5	0,6	20,5	2,9	0,1—0,2	0,5
24	Hajduszovát—1	886—892					3,6	6,4		50,7				8,6														0,7			7,1		22,9	0,8	0,1—0,2	0,05—0,1
25	Hajduszovát—1	1060—1066								0,7				37,6								1,3						0,7			4,0	7,4	48,3	0,9	0,1—0,125	0,05—0,1
26	Hajduszovát—1	1150—1156								0,8				29,8								0,8										11,9	56,7	0,9	0,1—0,125	0,1—0,2
27	Hajduszovát—1	1324—1334								1,8				20,2								0,9									2,8	2,8	71,5	1,2	0,1—0,2	0,1—0,2
28	Ebes—3	817—822		0,9			0,9	4,3			1,7			62,0	2,6							6,0									4,3	0,9	16,4	0,8	0,1—0,125	0,1—0,2
29	Ebes—3	957—962						1,8			0,9			73,2	0,9							1,8						0,9				0,9	19,6	0,8	0,1—0,2	0,1—0,2
30	Ebes—3	1500—1504		0,6	2,2			2,2			1,1			28,8	0,6			0,6				19,9						0,6		21,5	3,2	1,2	14,3	0,9	0,1—0,2	0,05—0,1
31	Debrecen—4	1,3—	24,6		11,6	4,1	3,0	7,6			1,0			5,6	2,1	1,5		0,5	2,1			13,6			0,5			0,5			6,1		15,6	3,1	0,1—0,125	0,2—0,3
32	Debrecen—4	28,4	21,9	6,1	12,2		7,9	9,7			1,8		0,6	2,4	0,6	1,3			3,7			12,2		1,3				1,3			6,1		10,9	2,3	0,1—0,125	0,2—0,4
33	Debrecen (Klinika)	33,5—37,0	25,4		21,2	1,2	5,5	7,3		1,1				0,6	1,6			0,6	2,8	1,6		12,4	0,6	0,6	0,6						1,1		15,8	2,2	0,1—0,2	0,2—0,5
34	Debrecen—4	50,3	5,3	3,1	7,9		11,6	12,1			2,1			3,6	3,1			0,5	2,1	1,1		22,1	0,5	1,1				1,1			5,3		17,4	1,4	0,1—0,125	0,1—0,2
35	Debrecen (Klinika)	99 —105	28,4		14,2		10,9	8,4						2,6		0,7			4,5	1,3		9,0											20,0	9,2	0,1—0,2	0,5—2,0
36	Debrecen (Klinika)	116 —127	14,2	1,3	10,0	0,4	12,9	4.2			2,2			3,1	0,8	0,4		0,4	7,1			12,9			0,4					9,4	1,7		18,6	3,9	0,1—0,2	0,5—0,1
37	Debrecen (Klinika)	127 —139	12,5		9,8		4,9	7,1			0,6			4,9	0,6							4,9		0,6				0,6		19,1	3,8	1,1	29,5	6,0	0,1—0,25	2,0—5,0
38	Mezőtúr	7—9	5,7		7,9	1,1	25,5	6,8		0,6	1,1	1,1		12,4	1,1			0,6	5,1	2,2	0,6	3,4		1,1							2,8	1,1	19,8	0,5	0,1—0,125	0,05—0,1
39	Mezőtúr	51—57	15,8	1,4	11,5	1,4	4,3	9,3			0,7			7,1	2,1			0,7	2,1			13,6		1,4							5,0	4,3	19,3	1,6	0,1—0,2	0,1—0,2
40	Mezőtúr	94—101	9,7	0,5	9,7	0,5	12,7	7,1	0,5		1,5			10,2	0,5	1,5			2,0	1,0		17,8		0,5		0,5		0,5			5,1	1,0	17,2	1,3	0,1—0,2	0,1—0,2
41	Mezőtúr	216—219	11,2	0,5	3,7	0,5	9,1	10,6	0,5		2,7	0,5		2,7	2,7	0,5	0,5	0,5	3,7	1,6		20,8									4,8	0,5	22,4	2,2	0,1—0,2	0,1—0,2
42	Mezőtúr	401—406	1,2	2,3	4,1		4,1	10,5			1,2			9,3	0,6	1,8		0,6	2,3	0,6	1,2	4,6	1,2	1,2				2,9			5,3		45,0	4,5	0,1—0,2	0,2—0,5
43	Mezőtúr	484—488			0,7	0,7		17,9			1,4			3,6	0,7			0,7	0,7	0,7		8,7									15,9		48,3	1,2	0,1—0,125	0,05—0,1
44	Mezőtúr	594—597		2,9	6,4	2,9	1,8	15,2			1,2			4,0	0,6	1,8			1,8	0,6		21,0	1,2	1,8						3,5	3,5	0,6	29,2	4,0	0,1—0,2	0,2—0,4
45	Mezőtúr	616—622		0,6	1,2	2,5	1,9	20,8			0,6			4,4	1,9	3,2	0,6			0,6		13,8	1,9					1,2		7,6	10,1		27,1	1,3	0,1—0,2	0,1—0,2
46	Szeghalom	5—8	7,5	1,5	9,5	2,0	17,5	6,0		1,0	1,5			9,0	1,0	0,5			2,0	0,5		6,5			0,5						1,5	0,5	31,5	3,8	0,1—0,2	0,1—0,2
47	Szeghalom	43,5—49	17,0	1,7	17,0	1,1	19,3	0,6	0,6	1,7	3,4	0,6		4,6	0,6	1,7			5,6	2,3		7,4		0,6							1,7	0,6	11,9	7,9	0,1—0,2	0,2—0,5
48	Szeghalom	230—235	2,9	0,5	4,9	0,5	8,5	8,5		1,0	2,9			8,9	1,9	0,5		0,5	1,9	0,5		14,4	1,0	1,0		0,5				8,5			30,7	2,3	0,1—0,2	0,2—0,3
49	Szeghalom	310—315	0,6	2,9	5,4	1,2	5,9	16,0	0,6		1,2			15,5	1,8				5,4	1,2		3,6						0,6			3,6	3,6	30,9	2,7	0,1—0,2	0,2—0,3
50	Szeghalom	349—357	4,7	0,4	6,2		14,1	7,9	0,9		0,9			15,1	0,9				3,8	1,5		7,9									2,9	0,9	31,9	3,0	0,1—0,2	0,2—0,3
51	Szeghalom	393—398	9,7	0,5	11,7	1,5	13,1	5,8		0,5	2,4			2,9	1,5				0,9	0,9		15,0	0,5	0,5							8,3		24,3	3,4	0,1—0,2	0,2—0,5
52	Tiszanána	50—58	1,7		3,3	0,6	7,2	2,8		1,7	3,9			1,7	4,5	0,6			1,2	1,2		50,6		0,6				1,7			5,0		11,7	1,2	0,1—0,125	0,05—0,1
53	Tiszanána	148—150	3,3	2,8	2,8	1,9	3,8	3,6			3,3	0,4		1,4	4,2			2,3	0,9	0,4		32,3	0,9	0,5						0,9	6,1		18,2	0,9	0,1—0,125	0,05—0,1
54	Balmazújváros—2	860—866			0,8			0,8			0,8			38,4				0,8				0,8			0,8						9,2	2,5	45,1	0,8	0,1—0,125	0,05—0,1
55	Karcagbucsa—2	1364—1369						1,5			1,4			10,1	2,9							20,3									15,5	1,4	36,9	0,8	0,1—0,2	0,2—0,4
56	Karcagbucsa—2	1386—1391		0,6			0,6	1,7		3,5	1,1		0,6	30,5	5,7							12,6									8,0	2,9	32,2	1,1	0,1—0,2	0,1—0,2
57	Karcagbucsa—2	1500—1504												86,2		0,6						2,5					3,8				1,9		5,0	1,5	0,1—0,1	0,1—0,2

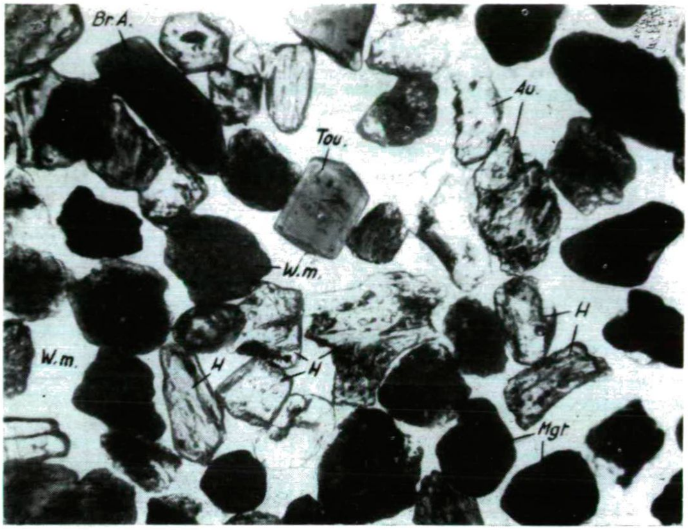

Figure 3 Heavy minerals sampled at 25 to 21 m, in the Törökszentmiklós boring (|| nicols, in nitrobenzene, fraction of 0,1 to 0,2 mm ∅). Magnification: 80—100×.

as their fringed ends are clearly seen. The columnar, somewhat darker mineral with clearer borders, on the left side of the figure, represent brown amphibole, the idiomorphic mineral in the centre is tourmaline.

The differences in the heavy-mineral composition of the materials sampled at the same depths in both of the borings, as well as the similarity of composition in the alluvia of present rivers proves that a river coming from the NW deposited its alluvia in the Szolnok area, whereas at Törökszentmiklós the deposits were transported by a river coming from the E or the NE, and filled up this part of the basin.

Sediments examined earlier and sampled at greater depths in the borings of Pély, Kisköre, to the North, as well as those situated to the South, at Gyoma and Szolnok, have shown that the river coming from the NW or the North, deposited older sediments as far as Gyoma, *i.e.* to the East and the South far beyond the present alluvial area *(Figure 1).* This finding is in accordance with the courses of the Upper Pliocene Palaeo-Zagyva and Palaeo-Sajó-Hernád drawn up by SÜMEGHY [1955]. URBANCSEK [1962] traced on this territory, the limits of the area of high-ferruginous artesian waters, which is in fairly good compliance with the deposition area of the original rivers above mentioned. The higher iron content of these sediments may be in connection, in addition to the aggressivity of water, with the larger amount of magnetite and limonite. KRIVÁN and MRS. NAGY, relying upon a palynological analysis of the material transported by the rivers, have proved that an erosion coming from the NW, originates in the Pannonian beds on the border of the Mátra Mountains, and had taken place in the Upper Pleistocene [KRIVÁN–MRS. NAGY 1963].

Fine or fine-grain sand has been sampled in the upper horizons of borings from Szolnok and Törökszentmiklós *(Figure 2).* In the lowermost horizon of the Szolnok boring, medium-grain *i.e.* coarser sand has been found as well; another expression of the differences between the depositions (erosion) of the lower and upper levels.

Profile N°. II *(Figure 4)* touches Karcag, Püspökladány and Kaba to the East of the former. The composition of the Kaba boring is characterized by hypersthene and augite playing an important role, together yet decreasing downwards (see Table). As it is known today the two characteristic minerals

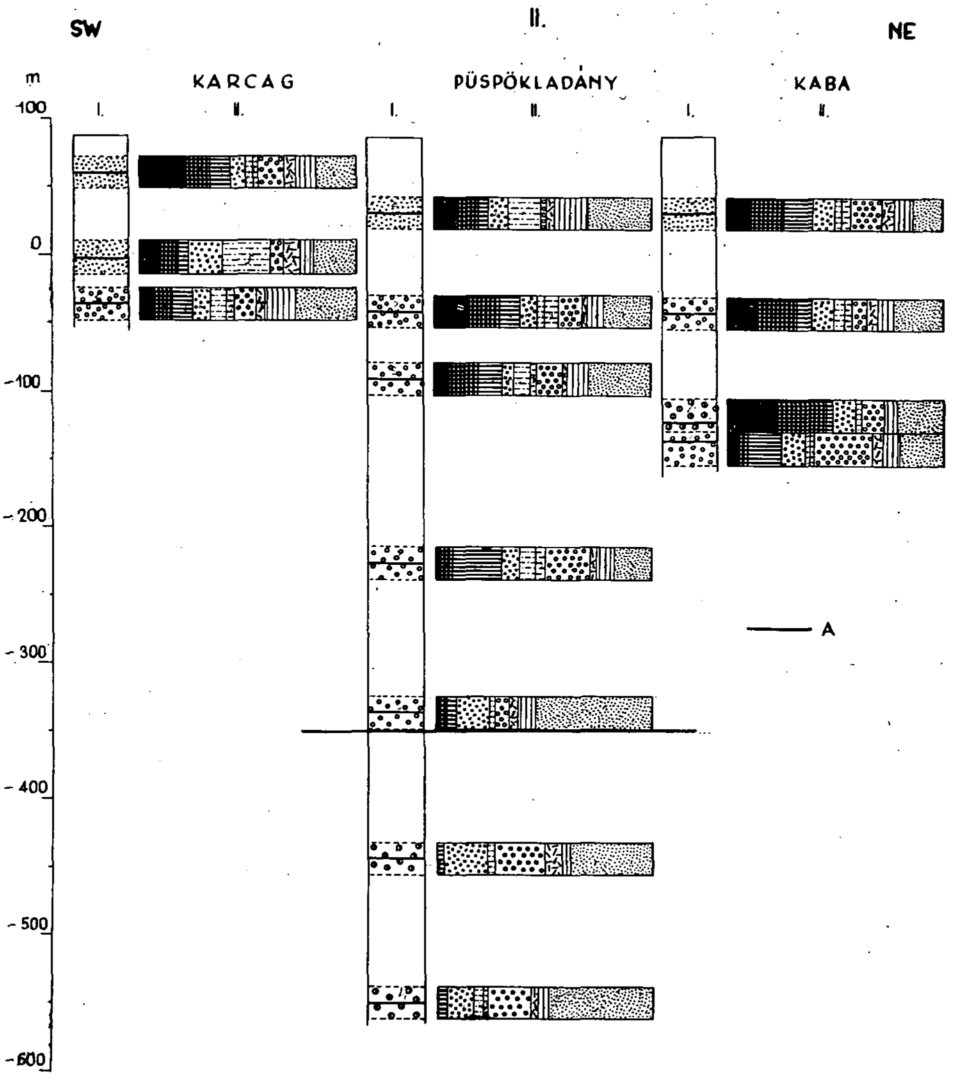

Figure 4 (Profile II). (For legends to granulometric and heavy-mineral composition see Figure 2)
A.: Lower limit of the sediments of the Tisza catchment area.

of the northern affluents of the Tisza and, to the NW of the Tisza, itself, are hypersthene and augite. In the alluvia of the Körös and the Maros coming from the East brown amphibole is also considerable. The sediment examined in the Karcag boring must have been transported to this place, from the NW, by the Palaeo-Tisza-Szamos as suggested by BULLA [1962]. The same holds true for the materials from the Püspökladány boring, with the difference that, at this place, the amount of brown amphibole is more increasing, while that of hypersthene and augite keeps decreasing probably upon the influence of the Körös.

The sample taken at a depth of 420 to 425 m represents a transition to the underlying sediments: below the sediments of the Tisza-river-system, sediments of a heavy-mineral composition differing from that of present alluvia have been found. The lower deposits are characterized by a small amount of brown amphibole and high magnetite and garnet content as well as by a large amount of weathered minerals (37 to 54%). Further data are needed to determine the direction and area of erosion of these formations.

In the last Kaba boring down to 211 metres, the composition is similar to the upper horizons of the borings mentioned above, *i.e.* it shows a NE direction of erosion. In the lowermost sample, taken at 216 m, the amount of brown amphibole is also larger, showing the effect of the Körös again.

This profile illustrates above all the regularity with which the alluvia of different rivers wedge out into each other. The sinking of the area is unequal, the rivers occupy each other's alluvial areas; consequently the sediments appear side by side and also above each other.

Profile N°. III *(Figure 5)* follows the line Hajdúszovát-Debrecen. The first, medium-grain sand sample suitable for examination was taken at 886 m in the Hajdúszovát N°. 1 prospecting well. According to investigations carried out in the Geological Laboratory at the Hungarian Petroleum and Gas Trust, there are Upper Pannonian beds at this depth. The heavy-mineral composition is quite different from the earlier facies discussed above. Biotite plays here the most important part. Its amount exceeds 50%. As to other minerals, brown amphibole (3,6%), magnetite (6,4%), chlorite (8,6%) and limonite (7,1%) probably altered from magnetite are also of importance. With the exception of chlorite, it is a characteristically magmatic mineral association. During the Upper Tertiary, particularly in the Helvetian stage, an intensive volcanic activity took place in this area. This activity produced also volcanic tuffites, and the Upper Pannonian sediments may partly be the result of the reworking of these products [KŐRÖSSY 1957]. Other Lower Pannonian sediments found in the Hajdúszovát well distinguish themselves by considerable amounts of chlorite and weathered minerals.

The heavy-mineral composition of the fine-grain sand sample taken in the Upper Pannonian strata of the Ebes-3 boring is very similar to that of the Lower Pannonian beds at Hajdúszovát, *i.e.* the role of chlorite is important, the weathered minerals are less considerable. In this boring, no Lower Pannonian sediments suitable for examination have been found. It is characteristic of the composition of the Upper Miocene sediments overlaid by the Lower Pannonian, that augite (2,2%), garnet (20%) and pyrite appear beside chlorite,

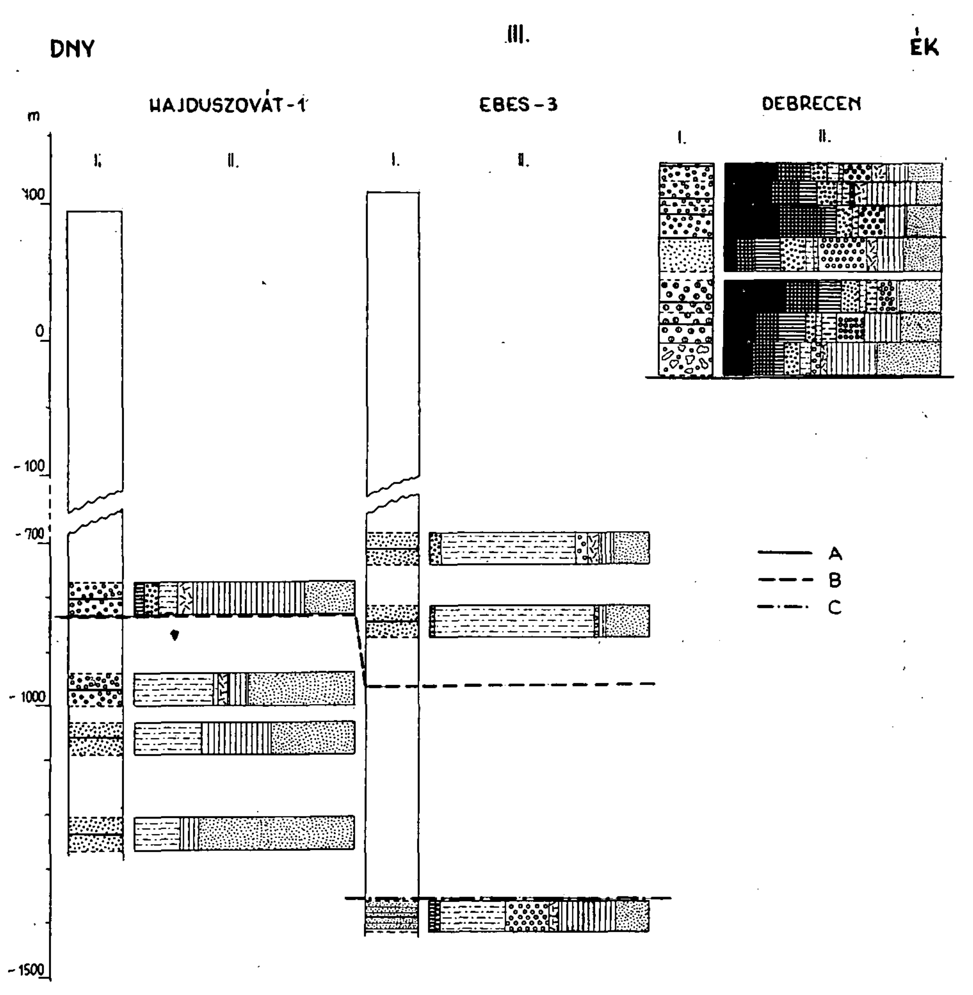

Figure 5 (Profile III). (For legends to granulometric and heavy-mineral composition see Figure 2)
A.: Lower limit of the sediments of the Tisza catchment area (?)
B.: Lower/Upper Pannonian limit
C.: Upper Miocene/Lower Pannonian limit

and that pyrite is gaining in importance. The large amount of pyrite represents a poorly aerated sea, *i.e.* a reducing environment.

In the Debrecen boring, samples from the upper horizon have been examined. With the exception of a sample from fine-grain sand, taken at 50 m, the charasteristic features in the composition of the NE rivers can be readily observed; hypersthene (12 to 28%) and augite (9 to 21%) play a particularly important role.

Figure 6 shows heavy-minerals in materials sampled at 1,3 m depth in the Debrecen boring, among other there are hypersthene, augite, garnet, mag-

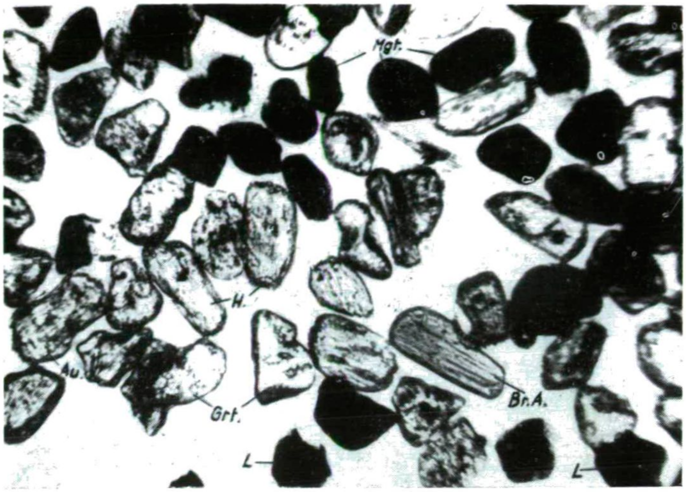

Figure 6 Heavy minerals from the 0,1 to 0,125 mm ∅ fraction at 1,3 m, in the Debrecen boring. (For embedding and magnification see Figure 3)

netite and limonite. *Figure 7* shows minerals of a sample taken at 33,5 m in the same boring, namely rounded hypersthenes as well as garnets, magnetites and limonites. Rounding-off is an effect of the wind: these grains come from the quick-sand sediments of the Nyirség, N and NW of the area.

Examinations carried out on the boring of Mezőtúr, have pointed out that also in this case the sediments were carried in, from the E and NE

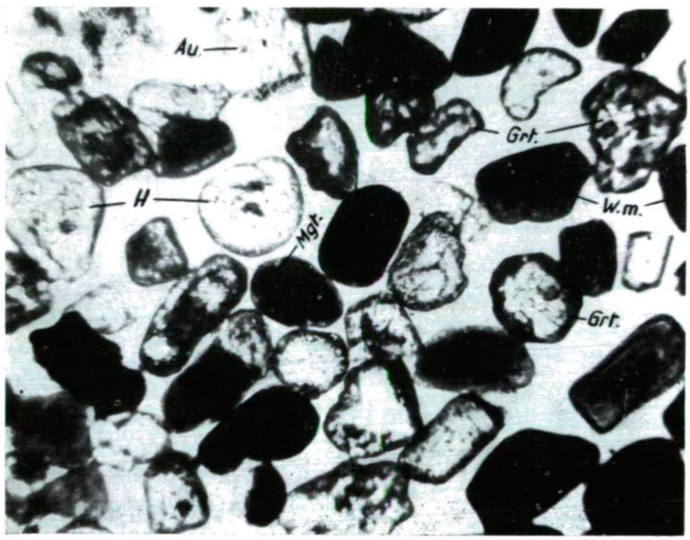

Figure 7 Heavy minerals from the 0,1 to 0,2 mm ∅ fraction, at 33,5 m, in the Debrecen boring. (For embedding and magnification; see Figure 3)

(*Figure 8* and Table). Down to 219 m, the dominant direction of transport is East, *i.e.* there are alluvias of the Körös. At 51 m, however, some NE effect can also be demonstrated: besides hypersthene and augite, brown amphiboles represent only 4,3%. Below 211 m, down to 622 m, the sediment rich in magnetite, limonite, garnet and weathered minerals. This formation may be correlated to sediments of similar composition at Pély, Kisköre, Szolnok and Gyoma, where eroded material was carried from the NW and N [MOLNÁR, 1964].

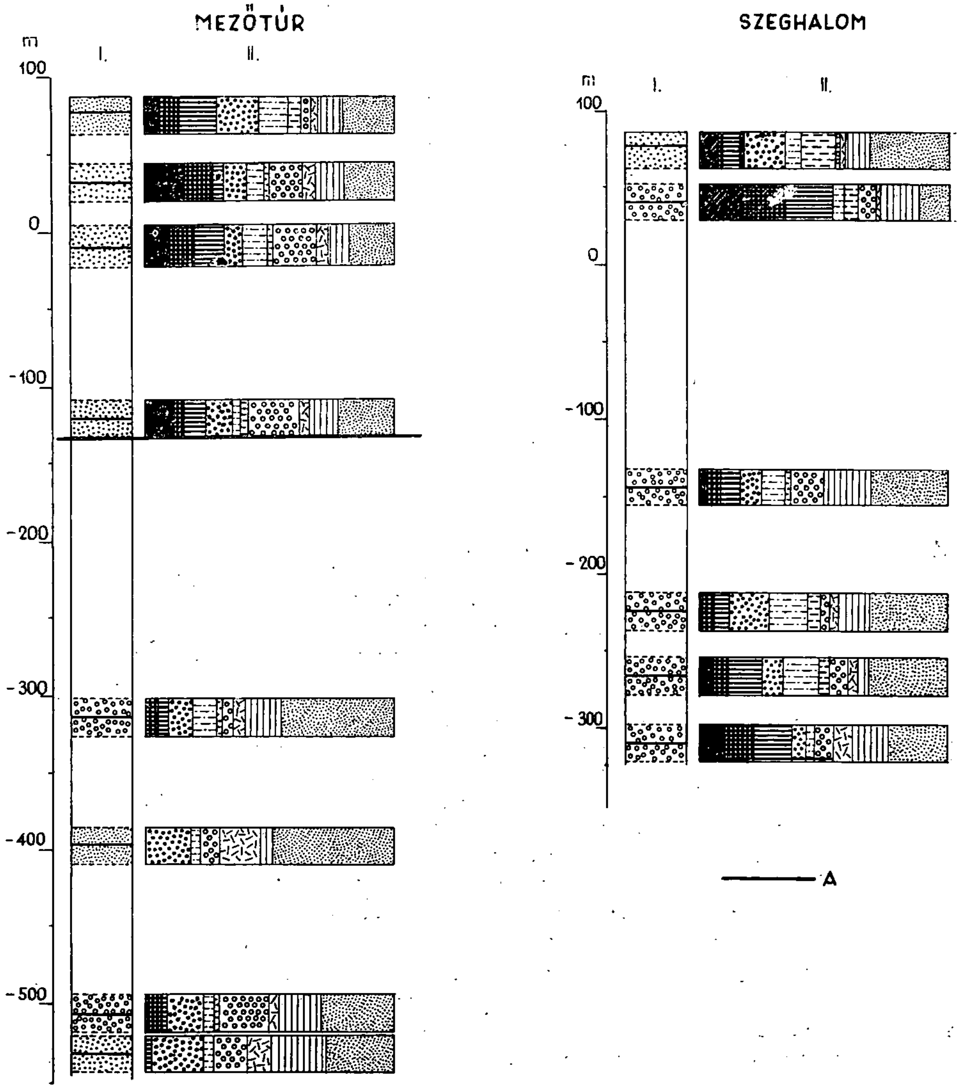

Figure 8 (For legends to granulometric and heavy-mineral composition see Figure 2)
A.: Lower limit of the sediments of the Tisza catchment-area.

With the exception of minor differences, alluvia of the Körös rivers can be demonstrated in the Szeghalom boring, down to 398 m (*Figure 8* and Table). *Figure 9* shows heavy minerals sampled at 43 m in the Szeghalom boring: for the most part it is hypersthene, augite and weathered minerals.

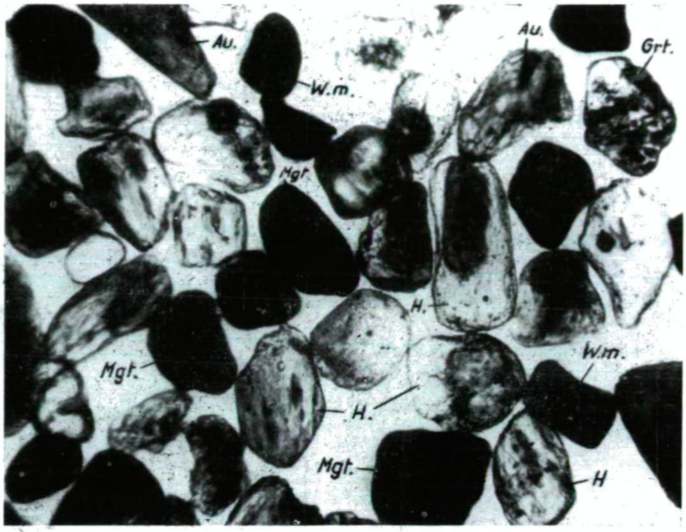

Figure 9 Heavy minerals from the 0,1 to 0,125 mm ∅ fraction, at 43,5 m, in the Szeghalom boring. (For embedding and magnification see Figure 3)

In *Figure 1*, the principal directions of stream erosion in the central part of the Tiszántúl have been outlined – and marked with arrows – on the basis of the above investigations and earlier studies. However, they do not accurately represent the alluvial area of each river, because, as it has been pointed out, the erosional areas of rivers intersect and wedge out into each other, as a consequence of uneven sinking which attracting one river or the other. In the NW, below the sediments of the present Tisza-system (the river Tisza and its affluents), an older phase of erosion can be still distinguished. It runs to the SE as far as the present Körös, and represents probably an erosion due to the Palaeo-Zagyva or Hernád-Sajó (*Figure 1*, N°. 2). The latter is overlaid by sediments showing a heavy-mineral composition similar to the alluvia of the present Zagyva, which may be traced to the East not farther than the Szolnok area, *i.e.* the deposits to be found at Törökszentmiklós have come from the NE and E (*Figure 1*, N° 3).

It is the task of further investigations to determine the directions of stream erosion of the sediments laying under the deposits of the NW and E parts of the Tisza-system (*Figure 1*, N° 3.)

According to the findings of heavy-mineral examination, the following major provinces, horizons, directions of stream-erosion and areas are to be distinguished in the Hungarian Basin:

1. Western, predominantly alpine (mainly metamorphic) stream-erosion area: the characteristic minerals of the sediments are diopside, large-size garnet, bluish-green amphibole (hornblende), calcite-dolomite, and a small amount of metamorphic minerals (chlorite, tourmaline, epidote, zoisite, tremolite-actinolite, staurolite, kyanite). Hypersthene and augite play quite a negligible role here. These sediments were deposited by the Danube during the Lower Pleistocene (Levantian) on the western part of the Great Plain (between the Danube and the Tisza), or they were blown out from the inundation area of the Danube and were accumulated as quicksand by the prevailing wind during the Upper Pleistocene on the ridges of the western part of the Great Plain [Miháltz 1961].

2. Sediments of the Tisza area (the Tisza and its affluents) where — because of the inner Carpathian volcanoes — the distinctive and characteristic minerals are hypersthene, augite and brown amphibole. These sediments were deposited during the Pleistocene by the Tisza and its affluents over the whole territory of Tiszántúl and the northeastern part of the area laying between the Danube and the Tisza. Within this province, the following sub-provinces can be distinguished:

a) sediments coming from the alluvia of the Zagyva: besides the above-mentioned minerals magnetite and garnet are also of importance;

b) products of erosion coming from the N and NE, characterized by hypersthene and augite. These sediments were chiefly deposited by the Tisza and its affluents an the northern part of the Tiszántúl, during the Plestocene;

c) erosional product of the Körös and Maros rivers, characterized by hypersthene, augite and brown amphibole appearing together. These sediments were mainly deposited by both rivers on the southern part of Tiszántúl, during the Pleistocene.

On the basis of data available, a thickness-map of sediments belonging to the Tisza catchment area may be drawn for a quite considerable part of the Tiszántúl. *Sc.* already elaborated borings passed for the most thinnest occur-this sedimentary complex (Figure 10). The map shows that the thinnest occurrence of this formation (not more than 50 m) appears in around Macs, on the uprising Pannonian table of Hajdúság. From hereon thickening appears towards the Tisza valley and Debrecen. At Kemecse the thickness is as much as 170 m. In the western part of Tiszántúl, the formation is first thickening parallel to the Tisza, to the E of the river, up to 150 or 250 m. In the environs of Gyoma, it is thinner again, but to the East of the latter region, in the Körös area it quickly becomes quite thick. In the frontier zone the thickness of this formation is as much as 500 m. Our thickness-map reflects the events and intensity of Quaternary crustal movements. The results are in good accordance with the development of crustal movements pointed out by other methods [Kertai 1957, Bartha 1962].

3. Fluviatile deposits overlaid by Tisza-catchment-area sediments in the southern part of Tiszántúl: these formations are characterized by the absence (or insignificant role) of hypersthene, and small amounts of augite and brown amphibole. Among metamorphic minerals, garnet, chlorite and bluish-green amphibole (hornblende) are more or less important. A considerable part of the sediments belonging to this area comes from the inner Carpathian volcanic territory and also from the denudation or reworking of other rocks. The composition is different from the alluvia of present rivers, as they were transported by one or other of the precursors of these rivers to the South-Tiszántúl

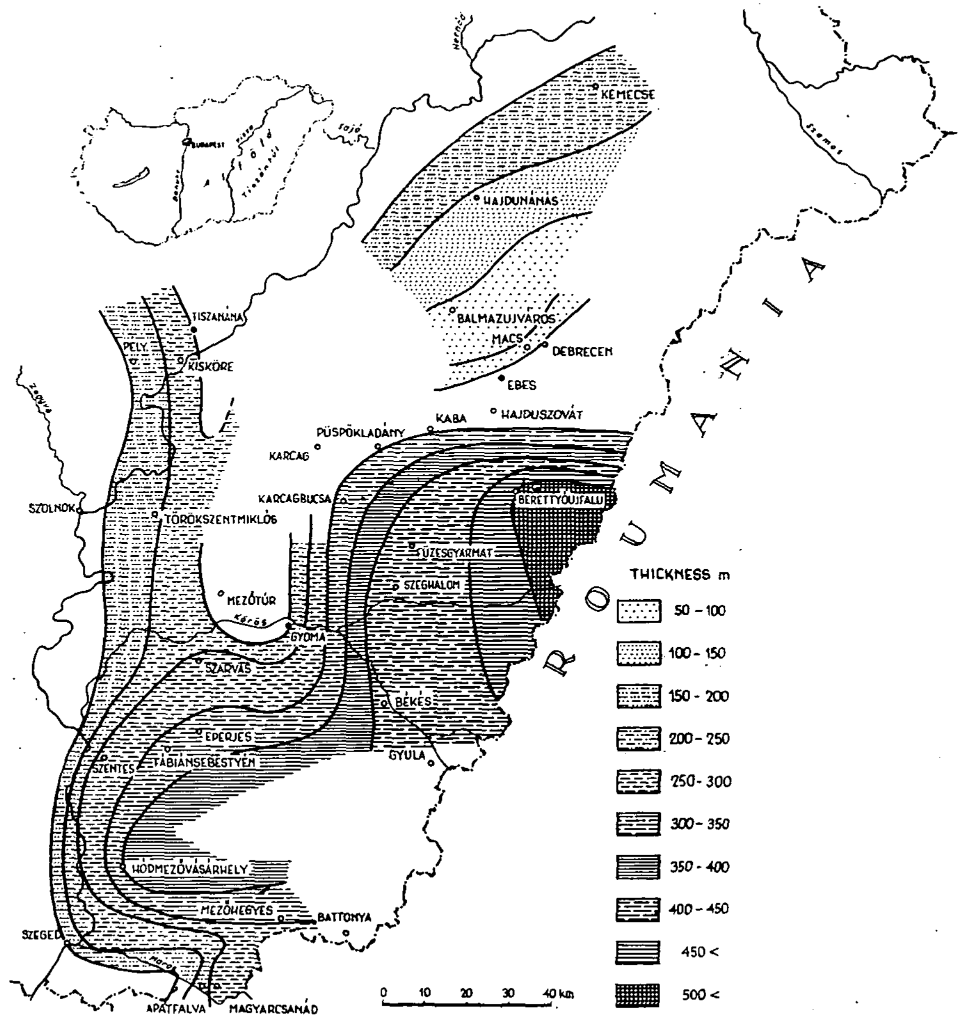

Figure 10 Thickness map of the sediments of the Tisza catchment-area.

area. With the help of the available data, it is very difficult to determine their age; they must have been deposited in the Lower Pleistocene or somewhat earlier.

4. The deposits of an assumed Palaeo-Zagyva—Sajó—Hernád river overlaid by the present-day Zagyva alluvia: this formation is characterized by larger amounts of magnetite and garnet than those found the present Zagyva-alluvia. This sediment must have been deposited during the Upper Pliocene (Levantian) and Lower Pleistocene.

5. In the northern part of Tiszántúl, the upper part of the Pannonian marine deposits are overlaid by sediments of the Tisza catchment-area; at Kemecse and Macs, these deposits are of different composition, but metamorphic minerals are dominant in their mineral association.

6. Upper Pannonian sediments, very rich in amphiboles and biotite, of North-Tiszántúl, opened by the borings of Macs, Kemecse and Hajdúszovát. This complex proves an Upper Tertiary volcanic activity in the area.

7. Lower and Upper Pannonian sediments of the southern part of the Great Plain; chlorites, the dominant minerals prove the Pannonian age of these formations.

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